

What is claimed is:

[Claim 1] A method for forming a thin high-k layer on a substrate, the method comprising:

providing a substrate in a process chamber;
depositing a high-k material to at least a minimum thickness to form a thick complete high-k layer on the substrate; and
thinning the thick complete high-k layer to a desired thickness less than the minimum thickness to form a thin complete high-k layer.

[Claim 2] The method according to claim 1, wherein the high-k material comprises Ta_2O_5 , TiO_2 , ZrO_2 , Al_2O_3 , Y_2O_3 , HfSiO_x , HfO_2 , ZrSiO_x , TaSiO_x , SrO_x , SrSiO_x , LaO_x , LaSiO_x , YO_x , or YSiO_x , or a combination of two or more thereof.

[Claim 3] The method according to claim 1, wherein the minimum thickness of the thick complete high-k layer is between about 30 Å and about 200 Å.

[Claim 4] The method according to claim 1, wherein the minimum thickness of the thick complete high-k layer is between about 50 Å and about 100 Å.

[Claim 5] The method according to claim 1, wherein the depositing comprises thermal chemical vapor deposition, plasma-enhanced chemical vapor deposition, atomic layer deposition, or physical vapor deposition.

[Claim 6] The method according to claim 1, wherein the desired thickness of the thin complete high-k layer is between about 5 Å and about 50 Å.

[Claim 7] The method according to claim 1, wherein the desired thickness of the thin complete high-k layer is between about 10 Å and about 30 Å.

[Claim 8] The method according to claim 1, wherein the providing comprises providing a substrate having an interface layer formed on the substrate and the depositing comprises depositing the high-k material on the interface layer.

[Claim 9] The method according to claim 8, wherein the interface layer comprises an oxide layer, a nitride layer, or an oxynitride layer, or a combination of two or more thereof.

[Claim 10] The method according to claim 1, wherein the thinning comprises exposing the deposited high-k layer to a plasma process.

[Claim 11] The method according to claim 10, wherein the plasma process comprises a process gas containing an inert gas.

[Claim 12] The method according to claim 11, wherein the inert gas comprises He, Ne, Ar, Kr, or Xe, or a combination of two or more thereof.

[Claim 13] The method according to claim 11, wherein the process gas further comprises a reactive gas.

[Claim 14] The method according to claim 13, wherein the reactive gas comprises HCl, HBr, Cl₂, Br₂, C_xH_yX_z, or C_xH_yX_z, or a combination of two or more thereof.

[Claim 15] The method according to claim 10, wherein the plasma process comprises etching the thick complete high-k layer in a reactive etching process.

[Claim 16] The method according to claim 10, wherein the plasma process comprises modifying a portion of the thick complete high-k layer and removing the modified portion using wet processing.

[Claim 17] A method for forming a thin hafnium-containing high-k layer on a substrate, the method comprising:

- providing a substrate in a process chamber, the substrate having an interface layer formed thereon;

- depositing a hafnium-containing high-k material to at least a minimum thickness necessary to form a thick complete hafnium-containing high-k layer on the interface layer in a TCVD process; and

- thinning the thick complete hafnium-containing high-k layer to a desired thickness less than the minimum thickness to form a thin complete hafnium-containing high-k layer.

[Claim 18] The method according to claim 17, wherein the minimum thickness of the thick complete hafnium-containing high-k layer is between about 30 Å and about 200 Å.

[Claim 19] The method according to claim 17, wherein the desired thickness of the thin complete hafnium-containing high-k layer is between about 5 Å and about 50 Å.

[Claim 20] The method according to claim 17, wherein the thinning comprises etching the deposited hafnium-containing high-k layer in a reactive etching process.

[Claim 21] The method according to claim 17, wherein the thinning comprises modifying a portion of the thick complete hafnium-containing high-k layer in a plasma process and removing the modified portion using wet processing.